

READER'S INK

THE TROUBLE WITH SUPERCAPS

I have never seen a formula estimating how long a supercap can back up NVRAM—which is surprising given the amount of interest in this subject lately. If you are going to design a supercap-backup system, you need to know how long it can last. If you've decided to use supercaps in your design, perhaps the following analysis will change your mind.

Let's compare the backup time of a 0.46-F supercap with that of the CR1632 lithium battery rated at 120 mAh (Dallas Semiconductor uses this battery in the popular NVRAM modules). The NVRAM used here will be typical of that used for battery-backed applications.

If the data retention current of the RAM is 1 μ A at 25°C and 12 μ A at 70°C. The battery can thus sustain the RAM contents at 25°C for:

$$\frac{120 \times 10^{-3} \text{ Ah}}{1 \times 10^{-6} \text{ A}} = 120,000 \text{ h or } 13.7 \text{ yr}$$

At 70°C, the backup time drops to:

$$\frac{120 \times 10^{-3} \text{ Ah}}{12 \times 10^{-6} \text{ A}} = 10,000 \text{ h or } 1.4 \text{ yr}$$

A different approach must be taken with a capacitor which uses a physical, rather than a chemical, process. The trick is to view this problem on the atomic scale. Since an ampere equals the flow of one coulomb per second and a coulomb equals 6.24×10^{18} e (electrons), we know that an amp-hour amounts to a charge of $(6.24 \times 10^{18} \text{ e/s}) \times 1 \text{ h} \times 3600 \text{ s/h}$ or 2.25×10^{22} e.

The formula $Q = CV$ relates the charge of a capacitor in coulombs to its voltage. If the capacitor is charged to 4 V, it will hold $0.47 \text{ F} \times 4 \text{ V}$ or 1.88 C of charge. If the capacitor is allowed to discharge to 2 V, it will then hold $0.47 \text{ F} \times 2 \text{ V}$ or 0.94 C of charge (the voltage range of 4–2 V is appropriate for the DS1210 nonvolatile controller IC). During this 2-V drop, the capacitor is allowed to source $1.88 \text{ C} - 0.94 \text{ C} = 0.94 \text{ C}$, which is atomically equivalent to 5.86×10^{18} e.

To put things back on familiar ground, let's convert this into a milliamp-hour rating:

$$1 \text{ mAh} = \frac{(6.24 \times 10^{18} \text{ e/s}) \times 1 \text{ h} \times 3600 \text{ s/h}}{1000} = 2.25 \times 10^{19} \text{ e}$$

Therefore, the capacitor supplies:

$$\frac{5.86 \times 10^{18} \text{ e}}{2.25 \times 10^{19} \text{ e/mAh}} = 0.26 \text{ mAh}$$

At 25°C, the supercap provides a backup time of:

$$t = \frac{0.26 \times 10^{-3} \text{ Ah}}{1 \times 10^{-6} \text{ A}} = 260 \text{ h or } 10.8 \text{ days}$$

At 70°C, the backup time drops to 21.67 h! Yikes! What's gonna happen with the automated plant when your controller goes down on a summer weekend?

Obviously, the decision to use supercaps for critical system backup must be made with care. I like to use a supercap as an emergency backup for the backup battery—a 3.3-F, 2.5-V cap is a good choice which supplies a couple of hundred hours of secondary backup.

The following table should help put the relative capacities of batteries and supercaps in perspective:

Power Source	Value	Capacity	Backup Time		
			@25°C	@40°C	@70°C
CR1632	144 F	120 mAh	13.7 yrs.	5.7 yrs.	1.1 yrs.
supercap	0.47 F	0.26 mAh	10.8 days	4.5 days	21.6 h

Note the very large equivalent capacitance of the batteries and the small equivalent capacity of capacitors.

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